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МЕТОДИКА ДЛЯ ТРАССИРОВКИ ЧАСТИЦ В ПОТОКЕ ЖИДКОСТИ С ИСПОЛЬЗОВАНИЕМ МЕТОДА ИЗМЕРЕНИЯ СКОРОСТИ ЧАСТИЦ (PIV)

METHODOLOGY FOR PARTICLE TRACING IN FLUID FLOW USING PARTICLE IMAGE VELOCIMETRY (PIV)

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Аннотация: В предварительных научных исследованиях, касающихся экспериментов с потоком жидкости, теперь очень важна скорость изображения частиц (PIV). Метод PIV представляет собой технику неинтрузивной визуализации потока, которая обеспечивает мгновенные поля скорости по глобальным доменам в отличие от существующей техники Шилерена и Shadowgraph. Для извлечения локальной скорости жидкости PIV записывает положение во времени мелких частиц-индикаторов, вводимых в поток жидкости. В этой статье мы сосредоточимся на методологии PIV, Экспериментальной схеме и возможности PIV.
Abstract: In prevenient scientific research regarding fluid flow experimentation, particle Image Velocimetry (PIV) became very important now-a-days. PIV technique is a non- intrusive flow visualization technique which provides instantaneous velocity fields over global domains unlike the existing Schileren and Shadowgraph technique. To extract the local fluid velocity PIV records the position over time of tiny tracer particles introduced into the fluid flow. In this paper we focus on the PIV methodology, Experimental arrangement and PIV feasibility.
Ключевые слова: цифровая велосиметрия; глобальная область; метод шилерена и шедограф; скорость жидкости.
Key words: PIV; global domain; schileren & shadowgraph technique; fluid velocity.

INTRODUCTION

In recent times PIV technique is strongly recommended for detailed quantitative velocity information in different aspect of scientific research including fluid flow. In case of gas-liquid two phase flow, gas-slurry bubble columns and other several cases PIV can be the worth technique for fluid flow measurement with flow visualization. Compared to other available techniques PIV technique can be an efficient way of measuring gross velocity structures of fluid field of area. PIV technique gives the measurement of fluid mechanic quantities like mean and rms velocities, temporal and spatial velocity moments, various velocity correlations, vorticity, circulation of the flow [1]. Experiments regarding fluid flow quantitative velocity measurements were conducted earlier using Pitot-static tubes. In terms of probe miniaturization, frequency response and ability to measure multiple velocity components hot-wire anemometers brought a significant advantage in early 1920s. Nevertheless, both the techniques require the insertion of physical probe which can intrude on the flow itself. Laser Doppler anemometer in the 1960s started a new entrant to enable non-intrusive velocity measurements. The design of such kind of techniques and associated electronics are at best Point-wise where velocity information is received only at the point occupied by the probe. On the other hand, PIV technique based on laser probe contains the ability to render global velocity (2D or 3D) measurements [2].

THEORETICAL APPROACH

According to the classification proposed by Hinsch [3], a measurement system can be labelled as (k, l, m), where k = 1, 2, 3 indicates the number of velocity components measured l = 0, 1, 2, 3 indicates the number of spatial dimensions of the measurement domain, and m = 0, 1 indicates instantaneous or continuous time recording, respectively. Accordingly, even the best point-wise techniques can only attain a (3, 0, 1) status. In contrast, the simplest form of PIV provides two-dimensional velocity data on a planar domain at discrete time instants, i.e. (2, 2, 0). The majority of PIV systems in use today belong to this category. Auto-correlation is performed when images from both laser pulses are recorded on the same sensor, i.e. the sensor shutter stays open during the time that both laser bursts occur. Such a recording is called single-frame/ double-pulse [4]. In case of correlation based PIV,The auto-correlation function R(S), of the intensity pattern, I(X), of the interrogation spot is $R(S)=\int_{spot} I(X)I(X+S)dX$ ..... (1)
A direct computation of the auto-correlation function by evaluating eq. (1) is prohibitively expensive. Instead, the auto-correlation function is computed via a two-dimensional Fast Fourier Transform (FFT) of the digitized intensity pattern. $R(S) = I(X) \star I(X) = I(X) * I(-X)$, where $\star$ represents the correlation operation, and * the convolution operation. Using the convolution theorem: $F\{R(S)\} = F\{I(X)\}.F^*\{I(X)\} = |F\{I(X)\}|^2$ where F -denotes the Fourier transform. Therefore,
$R(S) = F^{-1}\{F\{| I(X)\} |^2\}$

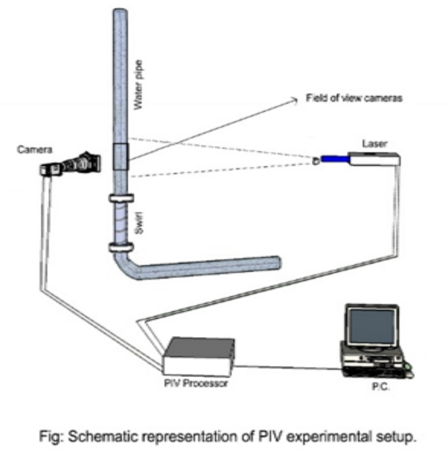

Fig. 1. Schematic diagram of PIV experimental settings

EXPERIMENTAL SETTINGS & RESULTS

PIV requires four basic components: (1) An optically transparent test-section/transparent water pipe containing the flow with tracer particles; (2) A light source (laser) to illuminate the region of interest (plane or volume); (3) Recording hardware consisting of either a CCD camera, or film, or holographic plates; (4) PIV processor; (5) A computer to extract the velocity information from the tracer particle positions.

MAJOR FIT OUT FUNCTIONS FOR PIV TECHNIQUES [5]

Speed optimization options: To increase processing speed intermediate processing step may use faster peak fitting algorithms or simpler image interpolation schemes. This may have a minor influence on the final result (e.g. reduced precision and/or reduced vector detection rate)
Vector Plotting Parameters: Show Vector Field – has to be enabled to show the vectors. If a data set is available, that is, the image is evaluated, then enabling this option will immediately display the vector field.
Vector Size / Spacing: Both the vector head length and width can be specified here. Also there is the choice to fill in the arrow heads.
Vector Stretch Factor: Specifies the amount the displacement is scaled with respect to the image. For example, a vector with length 10 pixels with a scale factor of 2.0 is 20 pixels long when plotted on the image. The stretch factor is always based on the pixel displacement of the data.
Maximum Vector: Can be used to avoid plotting vector whose length exceeds the value Specified (e.g. outliers). The magnitude is specified in pixels.
Spacing: This option allows vectors to be skipped and is useful when the data is too dense to be properly displayed.

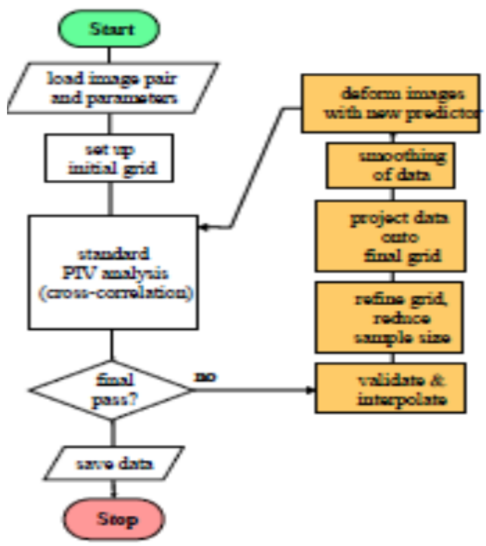

Fig. 2. Flowchart for processing with image deformation for second order accurate PIV interrogation

DISCUSSIONS

In spite of having significant role of PIV technique in fluid flow measurement, it's not beyond errors in some cases. PIV measurements contain errors arising from several sources: (1) Due to noise in the recorded images causes random error; (2) To process the signal peak location to sub-pixel accuracy in some cases arises Bias error; (3) Gradient error resulting from rotation and deformation of the flow within an interrogation spot leading to loss of correlation; (4) Tracking error resulting from the inability of a particle to follow the flow without slip; (5) Acceleration error caused by approximating the local Eulerian velocity from the Lagrangian motion of tracer particles. Certain errors can be minimized by careful selection of experimental conditions (for example, tracking error). However, other sources are inherent to the nature of the correlation in PIV and cannot be eliminated.

For the verification of turbulent theories or the evaluation of mathematical models flow visualization tool appears with some limitations. Such applications require extensive quantitative information about the fluid velocities, not just at a single point but at two or more points in the flow-field at the same time.

CONCLUSIONS

In this work we tried to discuss in brief about the PIV strategy and its experimental arrangements. As well it shows the comparison between other techniques and takes a point on the feasibility of PIV technique. This method for fluid flow measurement is very pragmatic and shows more accuracy. In this sense PIV is a logical denotation from qualitative to quantitative of the classical flow visualization technique compared to existing available techniques.

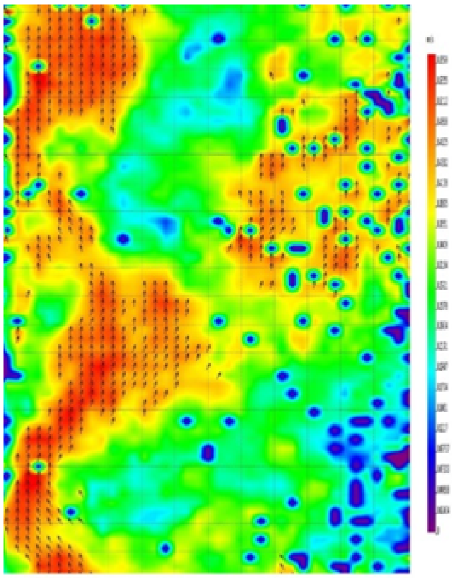

Fig. 3. Image showing vector field using PIV

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